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A COMPUTER DISPLAY SYSTEM FOR DYNAMICALLY MODIFYING STACKED AREA LINE GRAPHS TO CHANGE THE ORDER OR PRESENCE OF A SET OF STACKED AREAS IN THE GRAPH RESPECTIVELY REPRESENTATIVE OF THE PROPORTIONS CONTRIBUTED TO A TOTAL BY EACH OF A SET OF TIME DEPENDENT VARIABLES

Technical Field

The present invention relates to the display of graphs in interactive computer controlled display systems and particularly to the display of stacked area graphs.

Background of Related Art

Computers and their application programs are used in all aspects of business, industry and academic endeavors. In recent years, there has been a technological revolution driven by the convergence of the data processing industry with the consumer electronics industry. This advance has been even further accelerated by the extensive consumer and business involvement in the Internet. As a result of these changes, it seems as if virtually all aspects of human productivity in the industrialized world require human/computer interaction. The computer industry has been a force for bringing about great increases in business and industrial productivity.

In addition, the computer and computer related industries have benefitted from a rapidly increasing availability of data processing functions. Along with this benefit comes the problem of how to present the great number and variety of available elements to the interactive operator or user in display interfaces that are relatively easy to use. For many years, display graphs have been a widely used expedient for helping the user to keep track of and to organize and present

operative and available functions and elements on
computer controlled display systems. Computer displayed
graphs have been used to help the user or the user's
audience visualize and comprehend elements, and

5   particularly graphical elements that represent variables,
e.g. time dependent variables. For Example, XXX Inc. has
sales in Austin, Houston and Dallas over a given period
of time. The individual sales in each of the three
cities are time dependent variables. The respective

10   sales are elements that, when totalled, provide the total
sales of XXX, which is itself a time dependent variable.
In another example, the total temperature of a chemical
reaction of a given time period is a time dependent
variable. If the total temperature is the result of

15   temperatures contributed by three subprocesses, Temps. of
A + B + C = T (total) over the time period being
measured, then Temps: A, B and C are elements that, when
totalled, provide the total time dependent temperature.

         Time dependent systems in which a set of individual
20   time dependent variables each contribute to an overall
time dependent total are most effectively viewed and
presented on displays as stacked area line graphs with
the X axis as the baseline along which time is tracked.
With such an arrangement, the total of the time dependent

25   variable, e.g. temperature, will be the variable upper
line in the graph; and each of the elements
(subprocesses) contributing temperature will appear on
the stacked area graph as areas or layers, the thickness
of which is a visualization of the contribution of the

30   element to the overall total temperature.

         While such systems in which the set of elements each
contribute to the overall time dependent total may be
very effectively presented in the stacked area line

graphs as described above, there has not been an
effective system or method for manipulating the
individual contributing elements as represented by the
layers or areas in the stack.

5   Summary of the Present Invention

The present invention provides a user friendly
display interface that facilitates the presentation and
manipulation of a computer displayed stacked area line
graph. Accordingly, the broadest aspect of this
10   invention provides a computer implemented user
interactive system, method and computer program for
graphically displaying the proportion of a total value of
a time dependent variable contributed by each of a set of
elements. The invention is applicable in a graph
15   environment comprising the steps of displaying the
proportion contributed by each element as an area within
an ordered set of areas under a line representative of
the total value of said time dependent variable. In the
invention, the user is enabled to interactively select
20   one area in the set of areas and perform one of the
following operations: hiding the selected area,
displaying the selected area or reordering the position
of the selected area within said ordered set responsive
to said user selection. This implementation is effective
25   in the manipulation of stacked area line graphs by
visualizing how the various areas representative of the
contributions of the individual elements to the whole
time dependent variable affect and coact with the other
variables in the set. An area may be hidden, i.e.
30   removed from the graph, and one or more of the remaining
displayed areas reformed so as to represent the resulting
change of said reformed area within said ordered set of

stacked areas. Likewise, the effects of adding another
time dependent variable element represented by a new area
not previously in the area graph may be visualized by
inserting the new area and reforming the other areas to
5   absorb this new contribution. Also, the areas in the
stack may be ordered resulting in the reforming of up to
all of the areas in the stacked graph. The latter is a
particularly effective tool when the user wishes to see a
direct graph of the area ordered lowermost in the graph
10   with respect to the X-axis which functions as the time
line.

Brief Description of the Drawings

The present invention will be better understood and
its numerous objects and advantages will become more
15   apparent to those skilled in the art by reference to the
following drawings, in conjunction with the accompanying
specification, in which:

Fig. 1 is a block diagram of a interactive data
processing display system including a central processing
20   unit that is capable of displaying and implementing the
stacked area line graph manipulations of the present
invention;

Fig. 2 is a diagrammatic view of a display screen
illustrating a stacked area line graph showing the
25   contributions of three time dependent variable elements
as represented by a set of three areas to a whole time
dependent variable;

Fig. 3 is the view of the graph of Fig. 2 to show
the effect of hiding one of the stacked areas;
30   Fig. 4 is the view of the graph of Fig. 2 to show
the effect of reordering the sequence of the graphic
areas, as well as how the icons representing the

respective areas may be manipulated to effect the reordering;

Fig. 5 is an illustrative flowchart describing the setting up of the elements of a program according to the present invention for dynamic manipulation and reformation of the areas in a stacked area graph;

Fig. 6 is a flowchart of an illustrative run of the program set up in Fig. 5; and

Figs. 7 through 11 show the visualization sequence on the display when a stacked area graph like that of Fig. 2 is morphed through an animated sequence to a graph like that of Fig. 3 wherein a single area is shown along the X-axis.

Detailed Description of the Preferred Embodiment

Referring to Fig. 1, a typical data processing computer controlled display is shown that may function as a basic computer controlled Web receiving terminal used in implementing the present invention for displaying and manipulating stacked area line graphs. A central processing unit (CPU) 10, such as one of the PC microprocessors or workstations, e.g. RISC System/6000™ series available from International Business Machines Corporation (IBM), or Dell PC microprocessors, is provided and interconnected to various other components by system bus 12. An operating system 41 runs on CPU 10, provides control and is used to coordinate the function of the various components of Fig. 1. Operating system 41 may be one of the commercially available operating systems, such as IBM's AIX 6000™ operating system or Microsoft's WindowsXP™ or Windows2000™, as well as UNIX and other IBM AIX operating systems. Application programs 40, controlled by the system, are moved into and

out of the main memory Random Access Memory (RAM) 14.
These programs include the programs of the present
invention for the generation and manipulation of stacked
area line graphs that will be described hereinafter. A

5   Read Only Memory (ROM) 16 is connected to CPU 10 via bus
12 and includes the Basic Input/Output System (BIOS) that
controls the basic computer functions. RAM 14, I/O
adapter 18 and communications adapter 34 are also
interconnected to system bus 12. I/O adapter 18 may be a

10   Small Computer System Interface (SCSI) adapter that
communicates with the disk storage device 20.
Communications adapter 34 interconnects bus 12 with an
outside Internet or Web network. I/O devices are also
connected to system bus 12 via user interface adapter 22

15   and display adapter 36. Keyboard 24 and mouse 26 are all
interconnected to bus 12 through user interface adapter
22. It is through such input devices that the user may
interactively relate to the programs of this invention.
Display adapter 36 includes a frame buffer 39 that is a

20   storage device that holds a representation of each pixel
on the display screen 38. Images may be stored in frame
buffer 39 for display on monitor 38 through various
components, such as a digital to analog converter (not
shown) and the like. By using the aforementioned I/O

25   devices, a user is capable of inputting information to
the system through keyboard 24 or mouse 26 and receiving
output information from the system via display 38.

     The present invention involves the manipulation
rather than the creation of stacked area graphs on

30   computer controlled displays. Stacked area graphs are
conventionally generated so that the displayed areas
representative of the elements being presented are
displayed curves generated from a vector or from separate

columns in a matrix. The area function plots the values
in each column of a matrix representative of all the
curves in the stack as individual separate curves and
then fills in the area between the lowest curve and the

5   baseline X-axis, and then between the sequentially higher
curves and each other to produce stacked curves showing
the contribution of each row element (in the following
matrix for example) to the total height of the curve at
each X interval.

10                    $Y = \begin{bmatrix} 1 & 6 & 3 \\ 3 & 2 & 7 \\ 1 & 5 & 4 \\ 2 & 6 & 2 \end{bmatrix};$

     With this matrix, a stacked graph may be produced

15   with three graph areas, i.e. one per column, wherein the
height of the area graph is the sum of the elements in
each row and each successive curve uses the preceding
curve as its base.

     The somewhat more complex three area stacked area

20   line graph on the display screen 60 illustrated in Fig. 2
is formed in this manner. The stacked areas 63 at the X-
axis baseline and sequentially superimposed areas 62 and
61 represent elements that are time dependent variables,
such as temperature components contributed by each of a

25   set of chemical processes (elements) to a total
temperature line 64 over a 24 hour period during which
the process is being monitored. Each of the set of areas
61 through 63 is respectively controlled through a
corresponding icon 71 through 73 through which the areas

30   61 through 63 may be manipulated in accordance with the
invention. For example, in Fig. 3 icon 73 in Fig. 2 has
been pointed to and clicked on via a mouse. This has
caused area 63 to become hidden or removed from the

display in Fig. 3 and the two remaining areas, 61 and 62,
have been redrawn according to the stacked area rules
outlined above so that area 62 is now at the baseline X-
axis and area 61 extends above area 62. Icon 73 is now

5   displayed in outline 75 to represent that area 63 is
hidden. Now, if the user wishes to redisplay hidden area
63, icon outline 75 may be clicked on and the stacked
graph will be reformed to the graph illustrated in Fig.
2.

10   The areas in the stack may be reordered to any
suitable order in accordance with the user's needs. Fig.
4 illustrates how the areas may be reordered. For
simplicity in illustration, the reordering will be shown
using the two area stacked graph of Fig. 3. However, it

15   will be understood that the same icon reordering
movements may be used even if there are three or four
stacked areas. The bottom to top order of the icons
controls the same bottom to top order of the areas
respectively represented by the icons. Thus, when the

20   positions of icons 71 and 72 are switched in Fig. 4 as
indicated by the arrow lines so that icon 72 is now above
icon 71, there will be a corresponding reordering of
stacked areas so that area 62 is now above area 61. Line
64, which represents the total temperature, remains

25   unaffected by the change since no temperature component
was added to or removed from the stack.

Now, with reference to Fig. 5, we will describe a
process implemented by a program according to the present
invention for dynamically manipulating the areas in a

30   displayed stacked area graph. The program routines that
are created by the process of Fig. 5 implement the
operations described with respect to Figs. 2 through 4.
In a computer controlled display terminal as described in

Fig. 1, there is provided an operating system with a graphics engine, e.g. the graphics/text functions of Windows 2000™, which in turn translates the vectors provided for the areas in a stacked area graph into

5   dynamic pixel arrays providing the stacked graphs, step 80. A routine is set up for drawing stacked area line graphs on the user display, step 81. Then, routines are provided for hiding one of the areas in the stacked graph and for then regenerating the displayed stacked line

10   graph to show such a modification, step 82. Likewise, a routine is provided for adding the hidden area back into the stacked graph and for then regenerating the displayed stacked line graph to show such a modification, step 83. Finally, a routine is provided for changing the order of

15   the areas or elements in the stacked graph and for then regenerating the displayed stacked line graph to show such a reordering modification, step 84. There is also provided, step 85, a set of displayed icon buttons, each representing an element in the stack, as described in

20   Figs. 2 through 4 above, so that the user is enabled to modify the stacked line graph by carrying out steps 82 through 84 through pointing and clicking on the icon buttons. Also set up are routines responsive to the selection of an icon button for carrying out the step

25   represented by the selected icon, step 86.
       The running of the process set up in Fig. 5 and described in connection with Figs. 2 through 4 will now be described with respect to the flowchart of Fig. 6. First, at a computer controlled display terminal, data is

30   obtained for a set of time dependent variables that contribute to a total time dependent variable, step 90. Then, from this information, a stacked area graph is formed and displayed, step 91. First, step 92, a

determination is made as to whether the user is modifying
the stacked graph. If Yes, then a further determination
is made as to whether the modification involves hiding an
element or area in the stack, step 93. If Yes, the
5   hidden element is removed from the stacked graph, step
94, and the stacked area graph is regenerated to reflect
the change, step 95. If the determination in step 93 is
No, then a further determination is made as to whether
the user has selected to redisplay a hidden graph area,
10   step 97. If Yes, the hidden area is reinserted into the
stacked graph, step 98, and the process is returned to
step 95 where the stacked area graph is regenerated to
reflect the change. If the determination in step 97 is
No, then a further determination is made as to whether
15   the user has selected to reorder the area in the stacked
graph, step 99. If Yes, the order of the stack is
changed, step 100, as described above with respect to
Fig. 4, and the process is returned to step 95 where the
stacked area graph is regenerated to reflect the change.
20   After step 95, or if the determination in step 99 is No,
the process is branched to step 101 via branch "A" where
a determination is made as to whether the session is at
an end. If Yes, the session is exited. If No, the
process is returned to initial step 90 via branch "B".
25   As set forth above, an important aspect of the
present invention is the enabling of the user or viewer
to visualize the effects of the operations performed on
the areas representative of the elements that contribute
to the overall total. With Figs. 2 and 3 above, the
30   visualized effect was presented in a static manner with
Fig. 2 showing the initial state and Fig. 3 showing the
state of the stacked graph upon the completion of the
operation. With conventional image morphing techniques

currently available, such as those described in the text, <u>Bitmapped Graphics</u>, Igor Chebotko et al., published 1994, revised 2003, Wrox Press (available on the Web at: www.computerbooksonline.com), it is possible to animate
5 the transition between the image of the stacked graph before the selected operation is carried out and the stacked graph after the operation is completed. This is illustrated by Figs. 7 through 11. Fig. 7 is an illustration of the displayed initial stacked graph. It
10 has three stacked areas 110, 111 and 112. Each area represents an element that contributes to the total value of the time dependent variable as indicated by line 113. The operation selected to be performed on the graph of Fig. 7 is to hide areas 110 and 112 so that in Fig. 11
15 area 111 will remain as the bottom area so that it may be measured with respect to the baseline or X axis. The transition of the stacked graph between Figs. 7 and 11 is animated as shown via Figs. 8, 9 and 10. This animation enhances user interest and comprehension through this
20 animated visualization.

One of the preferred implementations of the present invention is in application program 40, i.e. a browser program made up of programming steps or instructions resident in RAM 14, Fig. 1, of a Web receiving station
25 and/or Web server during various Web operations. Until required by the computer system, the program instructions may be stored in another readable medium, e.g. in disk drive 20, or in a removable memory, such as an optical disk for use in a CD ROM computer input or in a floppy
30 disk for use in a floppy disk drive computer input. Further, the program instructions may be stored in the memory of another computer prior to use in the system of the present invention and transmitted over a Local Area

Network (LAN) or a Wide Area Network (WAN), such as the
Web itself, when required by the user of the present
invention. One skilled in the art should appreciate that
the processes controlling the present invention are
5   capable of being distributed in the form of computer
readable media of a variety of forms.

Although certain preferred embodiments have been
shown and described, it will be understood that many
changes and modifications may be made therein without
10 departing from the scope and intent of the appended
claims.